Friction Control in Planetary Gearbox by Selecting Grease with Proper Viscosity

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Abstract: ***The paper is directed towards the selection of proper viscosity grease to be used in a gearbox. Based on the pitch line velocity, the optimum viscosity is selected. A four stage planetary gearbox is employed for the test. Different losses responsible for efficiency loss were calculated. Major loss which is friction loss was targeted. The grease viscosity influences the frictional losses in the gearbox, hence various greases with different viscosities are used and the performance is tested. The test result showed that the selection of grease with viscosity close to the optimum viscosity improves the efficiency by 1.2%.***

Keywords: Viscosity, Grease, Efficiency, coefficient of friction, gears.

Nomenclature

INPUT DATA			
SR NO	DESCRIPTION	SYMBOL	VALUE
1	No of teeth on Gear	N_G	30
2	No of teeth on Pinion	Np	16
3	No of teeth on ring gear	N_R	76
4	Torque to be transmitted, mN-m	Tr.	3.48
5	Speed of Gear, rpm	n_G	3921
6	Speed of Pinion, rpm	n_P	8900
7	Pressure angle, in deg.	ϕ	20
8	Integer	u	10
9	Module, mm	m	0.35
10	Diametral Pitch (DP),	P	2.86
11	Face width, mm	F	6
12	No of stages		1
13	No of planet gears per stage		4
14	Frictional power	ws	
15	coefficient of friction	µ	
16	Rolling power	wr	

1. Introduction

The first question to be asked is, 'why viscosity of the grease is chosen to improve the efficiency of a gearbox?' The answer is described in the following lines. The gearbox in this paperuses a four wheel design using four planetary gears each stage. The outer diameter of the gearbox is as small as 32mm. Thus to modify the tooth profile or to super finish the gears will be very complex and costly affair. So it was decided to focus on the lubrication, thus to select the proper viscosity of the grease used for lubrication purpose will definitely help to reduce the frictional losses in the gearbox.

Figure 1: planetary Gearbox Internal view.

Points of extra interest:

- What are the total gearbox losses?
- What is individual gear mesh loss?
- What role the Lubricant plays?
- How kinematic viscosity affects the efficiency of the gearbox?

2. Mechanical Losses

The mechanical losses of the gearbox can be divided into different sub losses. These sub losses are:

- Sliding losses
- Rolling losses
- Wind age losses
- Gear bearing losses

2.1 Sliding losses

Frictional losses in gearbox are termed as sliding losses here. These are the losses caused due to friction between the contact surfaces of the gears in mesh. The amount of friction mainly depends upon the friction coefficient which again depends upon various factors, like surface roughness, sliding velocity, path of contact and viscosity of the lubricant to be used between the contact surfaces. Anderson & Loewenthal suggested an equation to estimate frictional losses [1],[4].

The power loss due to friction is given by:

$$Qs = \mu_s (x) . w_s(x) \quad (2)$$

2.2 Rolling losses

The losses which are taken into consideration besides sliding losses are rolling losses. These losses are generated due to high pressure developed between two meshing gears, and depend on the viscosity of the fluid used as a lubricant between the contact surfaces. Thicker the fluid more is the pressure developed and thus more rolling losses. The thickness of the fluid, i.e. viscosity thus needs to be properly selected to minimize these losses. An equation to compute these losses is also developed by Anderson & Loewenthal (Anderson & Loewenthal, 1980) [1],[4]. Analytical results showed that these losses mainly depend on rolling velocity. The rolling force is given by the equation:

$$F_r (x) = C_2. h_R(x) . f_w \quad (3)$$

Where F_r is the rolling force, h_R the fluid film thickness and is multiplied with a thermal reduction factor. Here the thermal factor is considered to be one, as exact value depends on many variables which are difficult to estimate. The normal force on tooth surfaces due to pitch line velocity is represented by f_w.Various calculations for efficiency were carried out on the basis of the analytical data obtained and the losses type taken into consideration.

The pie chart below shows what percentage of power loss is accounted for which type.

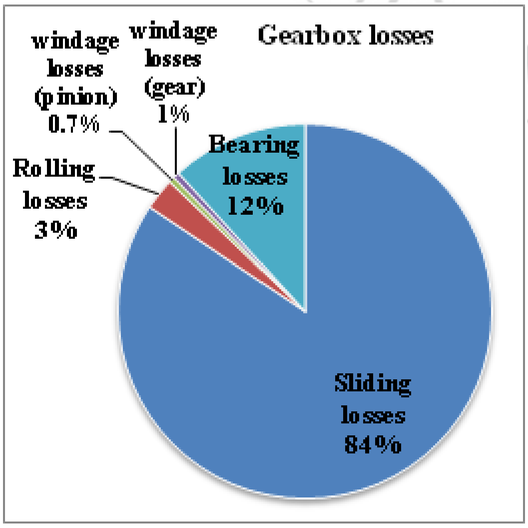

Figure 2: Percentage of loss shared by various types of losses

The pie chart shows that the Efficiency of the gearbox is mostly affected by gear mesh losses, and the gear mesh losses are mainly depend on the sliding losses. The factors that sliding losses depend on are coefficient of friction, surface roughness kinematic viscosity of the grease used, etc. From the calculations it is found that the sliding friction loss is proportional to the co efficient of friction [3]. Friction coefficient defines the friction losses in the gearbox.

2.3 Friction Coefficient

We require the value of friction coefficient to compute the sliding loss in Eq. (2),. Because many parameters such as lubricant viscosity rolling and sliding velocity, tooth surface roughness and normal load acting on tooth affect the friction coefficient, thus value of friction coefficient must be used based on these parameters. Many researchers suggested the empirical equation for computing the friction coefficient. These formulas are constructed based on the curve fitting of the results obtained from the gearbox efficiency test experiments, and the most accurate results are obtained using the one shown in Table 2. In the equation, *vk* and v_o are kinematic and dynamic viscosities of lubricant, *Vs* is the relative sliding velocity, *Vr*is the sum of the rolling velocities, *P*max is the maximum contact pressure and ϕ is the sliding loss ratio. Because these formulas had been constructed experimentally, they have restrictions according to their base experimental conditions. To use these formulas, input parameters in the calculation that are the values of lubricant parameters, surface roughness parameters, and operating parameters are previously checked carefully to assure that these formulas are applicable [1] [9].

Table 2: Formula for coefficient of friction

Empirical Formulae	*Published Author*
$\mu = [0.8\sqrt{\nu k\ Vs} + Vr\ \phi + 13.4]^{-1}$ $\phi = 0.47 - 0.13\ (10)^{-4} P_{max} - 0.4(10)^{-3} \nu k$	Drozdov and Gavrikov

The estimated results calculated by using the friction coefficient formula proposed by Drozdov and Gavrikov are the most accurate compared with the experimental results.

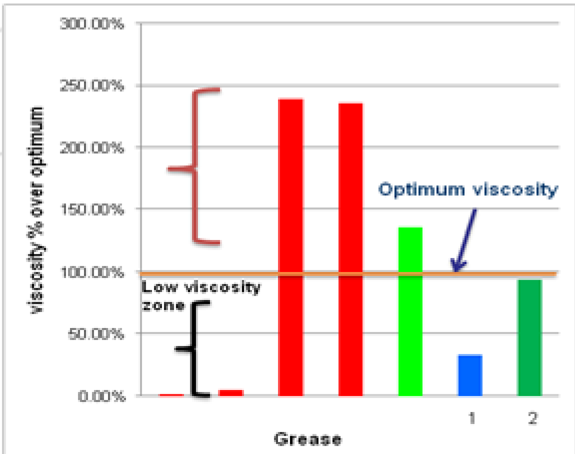

Figure 3: Viscosity of grease tried over the optimum viscosity

3. Lubrication

Gearboxes are lubricated with either grease or oil. Many variations of grease and oil exist with qualities such as: high temperature, low temperature, extreme pressure, water resistance, corrosion protection, etc. Lubrication is one of the most important components of a gearbox. Lubricant has two main purposes to serve. It keeps components from wearing and also keeps them cool. Most gearbox failures can be attributed to improper lubrication. Viscosity is a key attribute of the gear lubricant (grease in this case). The proper oil viscosity will provide an oil film between meshing gear teeth. This oil film is very thin and keeps the gear teeth from actually contacting each other. With too thin of a film or no film, failures such as scoring or wear will occur. By using grease KluberBarrierta L 55/2 the efficiency calculated for the planetary gearbox is approximately 89%. Seven different Greases are compared on the basis of their kinematic Viscosity and the graph is plotted against the efficiency (for first stage).Various greases with different kinematic viscosity have been taken , and calculation of friction coefficient is carried out keeping all other factors and losses constant. The following graphs were plotted on the basis of obtained values.

The pitch line speed of the gear is a goodindex of the required viscosity [8]. An empirical equation for determining required viscosity is

$$V_{40} = \frac{7000}{(v)^{\wedge}0.5}$$

Where,

V_{40} = Lubricant kinematic viscosity at 40^0C v = operating pitch line velocity. m/s

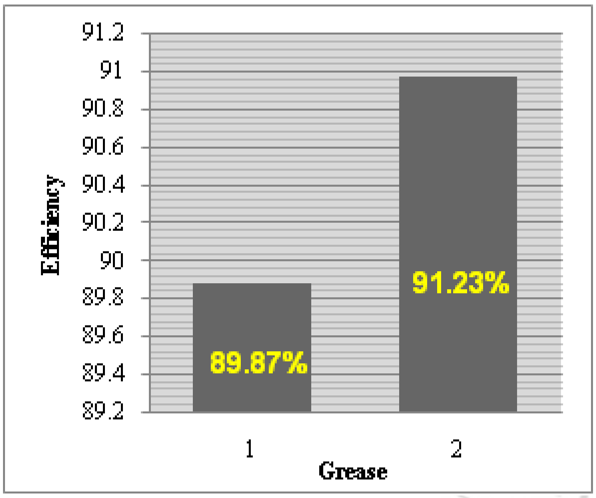

Figure 4: Efficiency of Gearbox with Existing grease Vs grease with optimum viscosity

4. Conclusion

Selecting a proper viscosity can help to control friction and thus improve efficiency of the gearbox. It was assumed that higher the viscosity of the lubricant, better will be the performance of the gearbox. But excessive viscous grease will lead to develop viscous drag and power loss thereby affecting the efficiency. The experimental results showed that the efficiency is increased by 1.2% using the grease 2 with viscosity close to the optimum viscosity, over the other greases. Grease 1 is the currently used grease.

References

[1] N. E. Anderson, and S. H. Loewenthal, “Effect of geometry and operating conditions on spur gear system power loss,” *J. Mech. Des.*, vol. 103, pp. 151-159, 1981.
[2] Y. N. Drozdov, and Y. A. Gavrikov, “Friction and scoring under the conditions of simultaneous rolling and sliding of bodies,” *Wear*, vol. 11, no. 4, pp. 291-302, 1968.
[3] G. H. Benedict, and B. W. Kelly, “Instantaneous coefficients of gear tooth friction,” *ASLE Trans.*, vol. 4, no. 1, pp. 59-70, 1961.
[4] GitinMaitra“ Hand book of Gear design (second edition)” page no.2.18, 2.19, 2.20, 2.21.
[5] Adam Lundin , Peter Mårdestam,“efficiency analysis of planetary gearbox.Linköping, September 2010
[6] ChakritYenti, SurinPhongsupasamit, and ChanatRatanasumawong* “Analytical and Experimental Investigation of Parameters Affecting Sliding Loss in a Spur Gear Pair” Department of Mechanical Engineering, Chulalongkorn University, Phayathai Rd., Patumwan, Bangkok 10330, Thailand.
[7] ISO TC 60, DTR 13989.
[8] The Lubrication of gears part –III Robert Enichell!o GiEARTIECH. Albany,.leA
[9] Efficiency analysis of a planetary gearbox. Adam Lundin ,Peter Mårdestam, Machine design
[10] Effects of kinematic viscosity of grease on Efficiency of a planetary gearbox. By Vivek Salve, Prof. R M Tayade, Praveen A. GhadiVolume : 4 | Issue : 3 | Mar 2015 ISSN - 2250-1991 39 | PARIPEX - INDIAN JOURNAL OF RESEARCH